

17. (New) The fuel injector according to claim 15, wherein the valve-closure member includes a spherical arrangement and the blind hole has a cylindrical form.

18. (New) The fuel injector according to claim 17, wherein the blind hole extends along a longitudinal valve axis.

19. (New) The fuel injector according to claim 11, wherein the spray-discharge region having the at least one outlet opening as a base part of a valve-seat member having the valve seat is convexly curved.

a) 20. (New). The fuel injector according to claim 11, wherein the fuel injector is configured to protrude into a combustion chamber of an externally ignited internal combustion engine.

21. (New) The fuel injector according to claim 11, wherein the fuel injector is configured to protrude into a combustion chamber of a self-igniting internal combustion engine.--.

REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1 to 10 in the underlying PCT Application No. PCT/DE01/02709. This Preliminary Amendment adds new claims 11 to 21. The new claims, inter alia, conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(iii) and 1.125(b)(2), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE01/02709 includes an International Search Report, dated December 28, 2001, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

It is respectfully submitted that the subject matter of the present application is new, non-obvious and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

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FUEL INJECTOR

[Background Information

] FIELD OF THE INVENTION

The present invention [is based on] relates to a fuel injector
[of the type set forth in the main claim].

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BACKGROUND INFORMATION

During operation of an engine, [the] a problem generally
occurs in the case of direct injection of a fuel into the
combustion chamber of an internal combustion engine,
10 particularly in the case of direct gasoline injection or the
injection of diesel fuel, that the downstream tip of the
injection valve projecting into the combustion chamber is
coked by fuel deposits or that soot particles formed in the
flame front are deposited on the valve tip. Therefore, in the
15 [case] conventional arrangement of injection valves projecting
into the combustion chamber [known heretofore], there is the
danger during its lifetime of a negative influence on the
spray parameter (e.g., static flow quantity, spray angle, drop
size, skeining) that can lead to operational disturbances of
20 the internal combustion engine or to a malfunction of the
injection valve.

[Summary of the Invention

] SUMMARY

25 The injector valve [of] according to the present invention
[having] may provide that the [characterizing features of the
main claim has the advantage that these previously mentioned]
negative effects of coking (soot depositing) [especially],
e.g., on the valve tip projecting into the combustion chamber
30 including its outlet openings [is], may be restricted or
eliminated. Forming a device for accumulating

combustion-chamber gas with access to the dead volume
[situated] arranged between valve needle end and the spray
region including the outlet openings in accordance with the
present invention makes it possible to largely prevent coke
5 deposits in the outlet openings. The buoyancy of the gas phase
with respect to the liquid phase causes the gas to remain in
the device for accumulating combustion chamber gas.

10 In this manner, the spray parameter and the valve function are
able to be maintained in a stable manner during its entire
lifetime even in the case of direct injection of fuel into a
combustion chamber at the fuel injection valves.

15 [The measures specified in the subclaims permit advantageous
further developments and improvements of the fuel injector
indicated in the main claim.

20 It is advantageous to provide one] One or more blind holes may
be provided on the valve needle end facing the outlet
openings, i.e., on the surface of the valve-closure member
facing the dead volume. In this context, it [must] may be
ensured that the blind holes have access to the dead volume
and that the gas volume is not able to escape from the gas
accumulation volume by buoyancy force.

25 [Brief Description of the Drawing

30 An exemplary] An example embodiment of the present invention
is represented in simplified form in the drawing, and is
explained in detail in the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

35 Figure 1 [shows] is a cross-sectional view of a part of a fuel
injector[, and]_.

Figure 2 [shows] is a schematic [section] cross-sectional view of an outlet opening having a breaking-off liquid column [situated] arranged therein.

5 [Description of the Exemplary Embodiments

] DETAILED DESCRIPTION

Figure 1 partially [shows] illustrates a valve in the form of an injection valve for fuel injection systems of mixture-compressing, externally ignited internal combustion
10 engines as an [exemplary] example embodiment. The injection valve has a tubular valve-seat support 1, in which a longitudinal opening 3 is formed concentrically to a longitudinal valve axis 2. [Situated] Arranged in longitudinal opening 3 is a, for example, tubular valve needle 5, which is
15 securely connected at [its] a downstream end 6 to a, for example, spherical valve closure member 7, on [whose] the periphery of which, for example, five flattenings 8 are provided for the fuel to flow past.

20 The fuel injector is actuated in a [known] conventional manner, e.g., electromagnetically. A schematically indicated electromagnetic circuit having magnetic coil 10, an armature 11, and an core 12 is used for axially moving valve needle 5, and as such, for opening the fuel injector against the spring
25 force of a restoring spring [(not shown)] and for closing the fuel injector. Armature 11 is connected, for example, by a welded seam formed by a laser to the end of valve needle 5 away from valve-closure member 7, and is aligned with core 12.

30 A guide opening 15 of a valve-seat member 16, which is sealingly mounted by welding in the downstream end of valve-seat support 1 away from core 12, in longitudinal opening 3, which [runs] extends concentrically to longitudinal valve axis 2, is used for guiding valve-closure member 7
35 during the axial movement. Valve-seat member 16 has a cupped

[design] configuration, for example, a jacket part 17 of valve-seat member 16 transitioning in the direction of armature 11 into a collar 18 abutting against valve-seat support 1. On the side opposite collar 18, valve-seat member

5 16 has a base part 19, which is convexly curved, for example.

The insertion depth of valve-seat member 16 determines the magnitude of the lift of valve needle 5 since the one end position of valve needle 5 in the case of a non-energized magnetic coil 10 is determined by the seating of valve-closure member 7 at valve-seat surface 22, which tapers conically in a downstream direction or has a slightly curved [design]

10 configuration, on base part 19 of valve-seat member 16. Given an energized magnetic coil 10, the other end position of valve

15 needle 5 is determined, e.g., by the seating of armature 11 on core 12. [Therefore, the] The path between these two end positions of valve needle 5 represents the lift. Spherical valve-closure member 7 cooperates with truncated-cone-shaped or curved valve-seat surface 22 of valve-seat member 16, which

20 is formed between guide opening 15 and a plurality of outlet openings 23 inserted in a central region of base part 19 of valve-seat member 16. Base part 19 forms the spray-discharge region of the fuel injector.

In particular, the fuel injector is [designed] configured as a so-called multi-hole valve that is particularly suited for injecting fuel directly into a combustion chamber[(not shown)]. In this context, at least [2] two or also four or significantly more outlet openings 23 are inserted in base

30 part 19 of valve-seat member 16, e.g., via erosive machining, laser drilling, [or] punching, etc. For a desired filling of the combustion chamber with fuel, outlet openings 23 are aligned, for example, at different angles to longitudinal valve axis 2, all outlet openings 23, for example, moving away

35 from longitudinal valve axis 2 in the downstream direction at an angle.

Especially such multi-hole valves for directly injecting fuel into a combustion chamber [whose] the outlet openings of which are directly subjected to the combustion chamber atmosphere are extremely susceptible to coking. [In an unfavorable case, such] Such outlet openings may have build-up on their periphery due to coke deposits, thereby making it impossible for the desired injection quantities to be dosed and metered in acceptable amounts.

The fuel injector [of] according to the present invention [is to] may largely prevent coke deposits of the combustion chamber in the region of outlet openings 23 from obstructing the outlet openings and significantly changing the injection quantities during the valve's lifetime.

Since valve-closure member 7 and curved base part 19 of valve-seat member 16 are formed with different radii, there is, when the injector valve is closed, an enclosed space representing a dead volume 25 within annular valve-seat surface 22 in the region of outlet openings 23, between valve-closure member 7 and base part 19. In accordance with the present invention, gas is to be accumulated in dead volume 25 in order to prevent coke deposits at outlet openings 23. Before this functional principle of gas accumulation is described, the creation of coke deposits is to be briefly explained [in the following].

The processes of through-flow and coking are subsequently explained [on the basis of] with reference to Figure 2, which schematically [shows] illustrates an outlet opening 23. When valve-closure member 7 is pressed back at the end of the injection operation onto valve-seat surface 22, the flow through outlet openings 23 is stopped abruptly. Therefore, no more fuel continues to flow through the sealing seat region past valve-seat surface 22 into dead volume 25.

Due to its weight, liquid column 27, which is emerging from outlet openings 23 immediately prior to the closing of the valve, possesses a certain inertia. The low pressure in liquid column 27 produced as a result of the closing of the valve and of the associated stop of the flow in the sealing seat region becomes greater as a function of inertia starting from an outlet plane 28 of outlet opening 23 in the downstream direction within outlet opening 23. At a certain location 29 within liquid column 27, the vapor pressure of the liquid is insufficient. A vapor phase forms suddenly at this location 29, thereby causing part 30 of liquid column 27, which is downstream of this location 29, to break away from the remaining liquid as a result of inertia.

A meniscus of liquid at which there is a phase boundary between the liquid and the gas surrounding the valve forms within outlet opening 23. When injecting fuel directly into a combustion chamber, all components directly on the combustion chamber, therefore also a direct injection valve, in particular outlet openings 23, which project into the combustion chamber, are subjected to an extreme influence of heat. During combustion, coke residues may form on the above-mentioned phase boundary in particular and build-up on the wall of outlet opening 23, thereby resulting in the previously explained disadvantages. Consequently, in the case of [known] conventional valves, annular coke deposits that disadvantageously constrict flow result at a certain depth in outlet openings 23.

In the [design] configuration of the fuel injector [of] according to the present invention, outlet openings 23 are completely emptied for which reason no coke deposits are able to form within outlet openings 23. In accordance with the present invention, a device for gas accumulation is, therefore, produced directly at dead volume 25. In the [exemplary] example embodiment [shown] illustrated in Figure

1, this device for gas accumulation is [designed] configured
as central blind hole 33 in valve-closure member 7 on its
surface facing dead volume 25. Blind hole 33 is filled with
combustion chamber gas, i.e., with the air dissolved in the
5 fuel. The buoyancy of the gas phase with respect to the liquid
phase causes the gas to remain in blind hole 33.

When opening the valve by raising valve-closure member 7 from
valve-seat surface 22, the fluid pressure in dead volume 25
10 increases, thereby compressing the gas volume in blind hole
33. In this context, the gas is pressed further into blind
hole 33. When closing the valve, the fluid pressure decreases
again, and the gas volume expands again within blind hole 33.
Since additional fluid is prevented from flowing into dead
15 volume 25 when the valve is closed, an underpressure is
produced in the liquid phase as a result of the inertia of the
just emerged fluid. As a result, the gas volume of blind hole
33 is able to expand even further, so that it partially
reaches into dead volume 25. The fluid volume expelled in this
20 manner is able to flow out of outlet opening 23.

While a pressure equilibrium returns in dead volume 25, the
remaining fluid volume recedes from outlet openings 23 into
dead volume 25 as a result of a contraction of the gas phase.
25 Outlet openings 23 fill completely with combustion chamber
gas. The liquid column disappears completely from outlet
openings 23. In this manner, there is also no more meniscus of
liquid column 27 in outlet opening 23 for which reason
disadvantageous, annular coking deposits are also not able to
30 form in outlet opening 23.

Instead of an individual blind hole 33, a plurality of smaller
blind holes 33 may also be provided next to one another on the
valve needle end facing outlet openings 23, i.e., on
35 valve-closure member 7. This [has] arrangement may provide the
advantage that given the same gas accumulation volume, the

cross section of individual blind holes 33 is smaller and, consequently, the capillary effect in blind holes 33 increases. Therefore, the accumulated gas is even less able to be expelled by flow forces of the liquid.

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The valve needle tip, i.e., valve-closure member 7 is not the only component part of the fuel injector on which blind holes of the present invention are able to be formed. Rather, it [must] may be ensured that blind holes 33 have access to dead volume 25 and that the gas volume is not able to escape from the gas accumulation volume by buoyancy force.

10

[Abstract

] **ABSTRACT**

[The present invention relates to a] **A** fuel injector, in particular a fuel injector protruding directly into a combustion chamber of an internal combustion engine, [having] **includes** an energizable actuator[(10, 11, 12)], a valve-closure member [(7)] able to be moved by the actuator[(10, 11, 12)], a secure valve seat[(22)], with which the valve-closure member [(7)] cooperates to open and close the valve, a fuel outlet formed in a downstream spray-discharge region and by at least one outlet opening [(23) situated] **arranged** downstream from valve seat[(22)], and a dead volume [(25)] formed downstream from valve seat [(22)] and upstream from the spray-discharge region having at least one outlet opening[(23)]. A device for accumulating combustion chamber gas is provided in the valve-closure member [(7)] in the form of a blind hole [(33)] having direct access to the dead volume[(25)].[

(Figure 1)]